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School ARventure: A design thinking framework for gamified augmented reality mathematics learning for students with intellectual disabilities

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Abstract

Background: Students with intellectual disabilities often experience difficulties in learning mathematics due to limitations in working memory, challenges in processing abstract symbols, and the limited availability of adaptive learning media in special education settings. In many special schools, mathematics instruction still relies on static physical manipulatives that provide limited opportunities to connect abstract mathematical ideas with meaningful learning experiences.
Aims: This study aims to propose a conceptual design framework called School ARventure, a gamified Augmented Reality mathematics learning environment integrated with a three-dimensional school model to support contextual mathematics learning for students with intellectual disabilities.
Method: This research employed a qualitative design guided by the Design Thinking framework, focusing on the stages of Empathize, Define, and Ideate. Data were collected through classroom observations, questionnaires, and semi structured interviews involving teachers and students from three special education schools. The instruments were validated by experts, and the data were analyzed using thematic analysis to identify learning barriers, user needs, and design requirements.
Results: The study produced an initial design framework addressing three main needs: concrete visualization of numerical quantities, reduced motor demands in measurement activities, and simplified representation of mathematical word problems. Three AR based features were conceptualized: AR Counting Adventure, AR Length Virtual Ruler, and Animated Story Quest, integrated with a physical school model as a contextual anchor.
Conclusion: The findings present School ARventure as a Design Thinking based framework for gamified Augmented Reality mathematics learning for students with intellectual disabilities and provide a foundation for future prototype development and empirical evaluation.

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INTRODUCTION

Improving access to meaningful mathematics learning for students with intellectual disabilities has become an important concern in inclusive education (Barr & Mavropoulou, 2021; Schnepel et al., 2024). Although many educational systems promote equal learning opportunities, students with intellectual disabilities often continue to experience difficulties when engaging with mathematical concepts. Mathematics learning frequently requires the ability to interpret symbols, understand quantitative relationships, and process abstract representations (Asenova et al., 2023; Munfaridah et al., 2021). For learners with limited working memory and slower cognitive processing,

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these demands can create substantial barriers to understanding. These challenges highlight the importance of developing learning environments that are capable of transforming abstract mathematical ideas into experiences that are more concrete, interactive, and accessible (Bini et al., 2024; Cheung, 2021).

Mathematics education plays a crucial role in developing reasoning, problem solving skills, and logical thinking. International frameworks such as Principles to Actions emphasize that effective mathematics instruction should foster conceptual understanding, encourage the use of meaningful representations, and promote active student engagement in learning processes. In Indonesia, policies supporting inclusive education also stress the need for curriculum adaptation, differentiated instruction, and accessible learning environments for students with special educational needs. These principles suggest that mathematics instruction must be designed in ways that accommodate diverse learners while maintaining meaningfu l learning experiences (Goyibova et al., 2025; Moleko, 2022).

Students with intellectual disabilities typically experience difficulties when dealing with abstract information and symbolic representations (Park et al., 2022; Strickland, 2022). Limitations in working memory, attention regulation, and language processing often make it challenging for these students to connect numerical symbols with the quantities they represent. As a result, students may struggle to understand mathematical relationships, follow multi step procedures, or interpret contextual problems presented in word form (Copur-Gencturk & Doleck, 2021; Hickendorff, 2021). Previous research indicates that learners with intellectual disabilities benefit from instructional strategies that emphasize concrete representations, simplified explanations, and repeated practice to gradually build conceptual understanding.

In many special education classrooms, mathematics instruction still relies heavily on conventional physical manipulatives such as counting blocks, number cards, or measuring tools (Byrne et al., 2023). While these materials help introduce mathematical ideas in concrete ways, they often remain static and limited in their ability to illustrate dynamic mathematical relationships. In addition, the limited interactivity of traditional materials may reduce students' engagement and restrict opportunities for independent exploration (Al Mamun & Lawrie, 2023; Muir et al., 2022). Consequently, learning activities frequently depend on continuous teacher assistance, which may limit students' autonomy in the learning process.

These conditions indicate the need for innovative learning media that can support more interactive and meaningful mathematics learning experiences (Daryanes et al., 2023; Engelbrecht & Borba, 2024). Technologies that combine visual representation, interaction, and contextual learning environments offer promising possibilities for addressing the learning needs of students with intellectual disabilities. Integrating digital technologies with familiar real world contexts may help bridge the gap between symbolic mathematical representations and students' everyday experiences (Swidan & Faggiano, 2022a).

Recent developments in educational technology have highlighted the potential of Augmented Reality (AR) as a tool for enriching learning environments (AlGerafi et al., 2023; Koumpouros, 2024a). AR technology allows digital objects to be superimposed onto real world settings, enabling learners to interact with three dimensional visualizations while remaining connected to their physical surroundings (Childs et al., 2024). Several studies have reported that AR can enhance conceptual understanding, increase student engagement, and support deeper learning experiences, particularly when abstract ideas are represented through interactive visual forms (Wen, 2021). In mathematics education, AR has been explored as a medium for supporting visualization and conceptual representation. By presenting mathematical objects in interactive three dimensional formats, AR can help learners understand relationships between quantities, spatial structures, and mathematical transformations that may be difficult to grasp through conventional instructional materials. In addition, AR based learning environments often create more engaging experiences that

can motivate students to participate actively in learning activities (Mokmin et al., 2024). Within special education contexts, AR has also been investigated as an assistive technology that can support learners with diverse cognitive needs. Research suggests that when AR applications are designed with simplified interfaces, clear instructions, and immediate visual feedback, they can help learners with intellectual or developmental disabilities understand both academic and functional tasks more effectively. The use of multimodal elements such as visual cues, audio guidance, and interactive manipulation can also help reduce cognitive load and facilitate information processing for learners with limited working memory capacity (Bali et al., 2025; Castro-Alonso et al., 2021).

Another important framework for inclusive learning design is Universal Design for Learning (UDL). UDL promotes the provision of multiple means of representation, engagement, and expression to accommodate learners with different abilities and learning preferences (Levey, 2023). In mathematics learning, this approach encourages the use of visual supports, simplified language, and interactive learning tools so that students can access mathematical concepts through various modes of interaction (Ion & Popescu, 2025). In addition to these pedagogical perspectives, Design Thinking has increasingly been adopted as a user centered approach for educational innovation (Guaman-Quintanilla et al., 2023; Velu, 2023). Design Thinking emphasizes understanding users' needs through empathy, defining problems based on real experiences, and generating creative solutions through iterative ideation. This approach is particularly relevant for designing learning technologies intended for students with intellectual disabilities, whose learning characteristics require thoughtful adaptation of both content and interaction design (Durgungoz & Durgungoz, 2025).

Despite the growing body of research on Augmented Reality in education, most AR based innovations have been developed for students in general education settings (Koumpouros, 2024b; Lampropoulos et al., 2022a). Studies that specifically address the needs of students with intellectual disabilities in mathematics learning remain limited. Moreover, many AR applications emphasize technological sophistication and visual complexity rather than carefully considering the cognitive characteristics of learners with intellectual disabilities (Almuaqel, 2024). Another limitation of previous research is the lack of integration between AR technology and meaningful real world learning contexts (Iqbal et al., 2022; Perifanou et al., 2023). Many AR applications present digital objects without linking them to familiar environments or everyday experiences. However, learners with intellectual disabilities often rely heavily on concrete contexts to understand abstract concepts, making contextualized learning environments particularly important for effective instruction. Furthermore, the development of educational technologies frequently follows traditional instructional design models that emphasize systematic procedures but provide limited opportunities to deeply understand users' learning experiences before designing technological solutions. As a result, some learning technologies may not fully reflect the actual needs and challenges faced by students with intellectual disabilities in classroom settings (Kharbat et al., 2020).

Considering these challenges, integrating AR technology with a user centered design approach offers promising opportunities for improving the accessibility of mathematics learning (Weinhandl et al., 2024). By combining interactive visualizations with contextual physical environments and simplified interaction mechanisms, mathematical concepts can be presented in ways that are more concrete and easier to understand. The concept of School ARventure is proposed in this study as a learning environment that integrates a three dimensional school model with AR based digital interactions and light gamification elements. Within this environment, mathematical learning activities are embedded in familiar school contexts such as classrooms, libraries, and other school spaces. This contextual approach allows students to connect mathematical ideas with their everyday experiences while interacting with digital representations (Swidan & Faggiano, 2022). The use of Design Thinking ensures that the conceptual framework developed in this study is grounded

in the real needs of students and teachers in special education environments. Through stages of empathy, problem definition, and creative ideation, the framework aims to generate learning media designs that are both pedagogically meaningful and accessible (Jamal et al., 2021).

Based on the identified research gaps, this study aims to develop a conceptual design framework called School ARventure, which integrates gamified Augmented Reality with a physical school model to support mathematics learning for students with intellectual disabilities. The study focuses on identifying user needs, defining key challenges in mathematics learning for students with intellectual disabilities, and proposing AR based design features that can transform abstract mathematical concepts into more concrete and interactive learning experiences. The findings of this study are expected to provide a conceptual foundation for the development of inclusive mathematics learning media and to guide future research involving prototype development, usability evaluation, and empirical investigation within special education contexts.

METHOD

Research Design

This study adopted a qualitative design grounded in the Design Thinking framework to formulate a conceptual model for Augmented Reality based mathematics learning. The choice of this approach was motivated by its emphasis on a human centered design process that begins with understanding users' experiences before proposing technological solutions. Such an approach is particularly relevant in the context of special education, where instructional tools must be carefully adapted to students' cognitive characteristics and learning needs. The research focused on three initial phases of the Design Thinking process: Empathize, Define, and Ideate. During the Empathize phase, the study explored the learning experiences of students with intellectual disabilities and identified the challenges they encounter in mathematics classrooms. The Define phase involved synthesizing the information gathered during the first stage in order to formulate the key instructional problems and design requirements. In the Ideate phase, these findings were translated into possible design solutions that could support more accessible mathematics learning through AR based interaction. Through these stages, the study aimed to move systematically from identifying users' needs toward generating a conceptual design for AR supported learning media. The sequence of the research process based on the Design Thinking framework is presented in Figure 1.

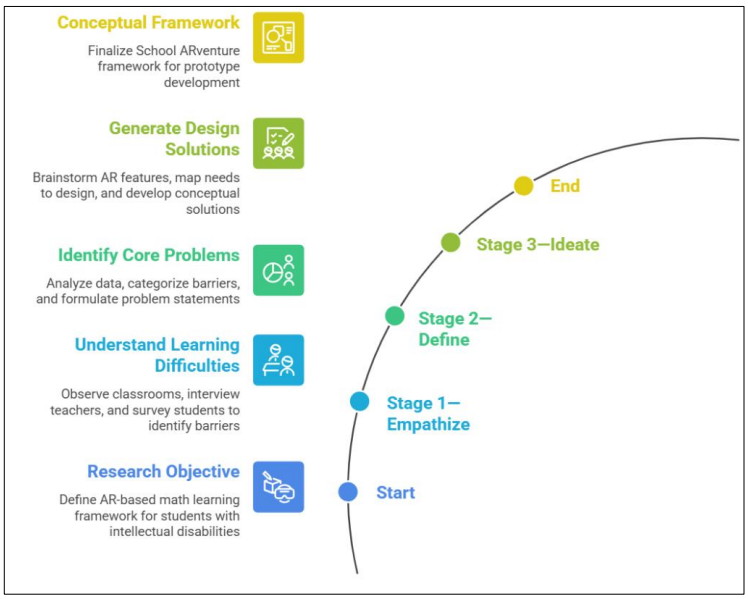

Figure 1. Research design based on the Design Thinking framework used to develop the School ARventure conceptual model

Participants

The participants involved in this study consisted of students with intellectual disabilities and teachers from three special education schools (SLB) in Semarang, Indonesia. Participants were selected through purposive sampling to ensure that those involved had direct experience with mathematics learning in special education settings. A total of 56 students with intellectual disabilities participated in the study. Based on school psychological records and educational assessments, 34 students were categorized as having mild intellectual disabilities and 22 students were identified as having moderate intellectual disabilities. The students were between 16 and 19 years old, with an average age of approximately 17 years. In addition, seven teachers were involved in the study. All participating teachers had experience teaching students with intellectual disabilities and were actively engaged in mathematics or numeracy instruction. Their perspectives were essential for identifying instructional barriers and evaluating potential technological solutions for supporting students' learning.

Research Procedure

The main outcome of this study was a conceptual design framework called School ARventure, which integrates Augmented Reality interaction with a three dimensional representation of a school environment and simple gamification elements. The framework was developed based on insights derived from the Design Thinking stages. School ARventure is designed as an interactive learning environment in which mathematical activities are embedded within familiar school contexts. The conceptual design includes several AR based learning features intended to support different mathematical concepts. For example, AR Counting Adventure allows students to interact with virtual objects to explore numbers and basic operations, while AR Length Virtual Ruler helps students practice measuring objects without relying on precise motor control. Another feature, Animated Story Quest, presents word problems through visual narratives to reduce the cognitive load associated with reading complex textual instructions. By combining physical models of school spaces with AR based digital interaction, the School ARventure framework aims to transform abstract mathematical ideas into learning experiences that are more concrete and accessible for students with intellectual disabilities.

Instruments

Data for this study were collected through classroom observations, questionnaires, and semi structured interviews. These instruments were used to capture information about students' learning experiences, instructional challenges faced by teachers, and potential opportunities for integrating AR technology into mathematics instruction. Student questionnaires were designed using a simplified format that incorporated three visual icons representing positive, neutral, and negative responses. This format was chosen to accommodate students' communication abilities and reduce the complexity of the response process. During data collection, the researcher read each question aloud and teachers assisted in ensuring that students understood the items before responding. Teacher questionnaires employed a four point scale to examine issues such as instructional challenges, cognitive load during learning activities, and the feasibility of integrating technology based learning media in special education classrooms. Semi structured interviews were also conducted with teachers and several students who were able to express their experiences verbally. Before the instruments were administered, they were reviewed by three experts in special education and educational technology to ensure that the items were appropriate for the target participants. The relationship between the data sources and research instruments used in this study is summarized in Table 1.

Table 1. Data Collection Methods and Research Instruments

Data Source	Instrument	Purpose	Participants
Classroom observation	Observation sheet	Identify learning barriers and classroom interaction patterns	Students with intellectual disabilities
Student questionnaire	Simplified icon based questionnaire	Explore students' learning difficulties and learning preferences	Students with intellectual disabilities
Teacher questionnaire	Four point scale questionnaire	Identify instructional challenges and evaluate feasibility of AR based learning media	Teachers
Interviews	Semi structured interview guide	Obtain deeper insights into mathematics learning challenges and potential design solutions	Teachers and selected students

Data Analysis

The collected data were examined using qualitative thematic analysis guided by the stages of the Design Thinking framework. The analysis began with repeated reading of observation notes, interview transcripts, and questionnaire responses in order to gain a comprehensive understanding of the learning context. During the Empathize phase, the data were coded to identify recurring patterns related to students' learning difficulties, classroom interaction, and instructional challenges observed during mathematics lessons. These codes were subsequently grouped into broader categories that represented common learning barriers experienced by the participants. In the Define phase, the categories identified in the previous step were synthesized to formulate key problem statements describing the most significant challenges in mathematics learning for students with intellectual disabilities. These problem statements served as the basis for determining design requirements for the proposed learning media. Finally, in the Ideate phase, the design requirements were translated into conceptual design ideas that later formed the basis of the School ARventure framework. This stage involved generating possible AR based features and mapping how these features could respond to the learning needs identified during the earlier phases. The resulting conceptual framework represents the integration of user insights, pedagogical considerations, and technological possibilities derived from the Design Thinking process.

RESULTS AND DISCUSSION

Results

The results of this study describe the development of the School ARventure conceptual framework through the first three stages of the Design Thinking process: Empathize, Define, and Ideate. These stages were used to systematically explore students' learning challenges, formulate the core instructional problem, and generate design solutions for Augmented Reality based mathematics learning for students with intellectual disabilities. The findings illustrate how the identified learning needs informed the development of the proposed learning environment.

Empathize Stage: Identifying Learning Barriers

The empathize stage aimed to understand the difficulties experienced by students with intellectual disabilities during mathematics learning activities. Data were collected through classroom observations, student questionnaires, and interviews with teachers in special education schools. This stage focused on capturing the actual learning experiences of students as well as the instructional challenges faced by teachers. The findings indicate that students often rely heavily on concrete objects when learning mathematical concepts. However, the use of conventional learning tools frequently fails to maintain students' engagement because the materials tend to be static and

offer limited interaction. As a result, students may lose attention during learning activities or require continuous assistance from teachers to complete tasks.

Three primary learning barriers were identified during this stage. The first barrier concerns students' difficulty in connecting numerical symbols with their corresponding quantities. Teachers reported that some students were able to verbally mention numbers but struggled to interpret what those numbers represented in terms of actual quantities. Observations also showed that students frequently repeated counting processes and sought confirmation from the teacher before proceeding. The second barrier relates to difficulties in measurement activities. When students were asked to measure objects using a conventional ruler, many of them struggled to align the ruler correctly with the object being measured. Limited eye–hand coordination and motor control often caused the ruler to shift during measurement, which led to inaccurate results and interruptions in the learning process.

The third barrier was observed in the context of mathematical word problems. Teachers explained that students often experienced cognitive overload when problems were presented in long textual descriptions. During observations, several students requested that the teacher read the problem repeatedly before attempting to interpret the numerical information contained in the text. These findings suggest that students with intellectual disabilities require learning environments that can reduce cognitive and motor demands while supporting the transition from concrete experiences to symbolic mathematical representations. From an inclusive education perspective, these needs align with the principles of Universal Design for Learning, which emphasize flexible representation of learning content and accessible learning interactions. The relationship between the identified learning barriers and the corresponding Universal Design for Learning principles is summarized in Table 2.

Table 2. Relationship between learning barriers and Universal Design for Learning principles

Identified Learning Barrier	Learning Challenge Observed	Relevant UDL Principle	Implication for Learning Design
Difficulty connecting numbers with quantities	Students could verbally mention numbers but struggled to interpret their meaning in terms of actual quantities	Multiple means of representation	Provide visual and interactive representations that link numbers to concrete objects
Difficulty using measurement tools	Students had trouble aligning rulers correctly due to limited motor coordination	Multiple means of action and expression	Design measurement tools that minimize fine motor demands through digital assistance
Cognitive overload in word problems	Students experienced confusion when problems were presented in long textual descriptions	Multiple means of representation and engagement	Present contextual problems through visual narratives and simplified instructions

Define Stage: Formulating the Core Learning Problem

Following the empathize stage, the collected data were analyzed to identify the central instructional issue underlying the observed learning barriers. The analysis revealed that the main challenge in mathematics learning for students with intellectual disabilities is not solely related to their basic numeracy abilities. Instead, the difficulty largely arises from the absence of learning media capable of bridging abstract mathematical concepts with concrete experiences.

Conventional instructional approaches often require students to interpret symbolic representations, manipulate objects with precise motor control, or process lengthy textual explanations. For learners with intellectual disabilities, these demands can create additional obstacles that hinder their conceptual understanding. Consequently, learning activities may become

overly dependent on teacher assistance, limiting students' opportunities to engage independently with mathematical concepts.

Based on this analysis, the study identified several design requirements for a more accessible learning environment. The proposed learning media should provide clear visual representations of mathematical concepts, minimize the need for precise motor coordination during interaction, and present contextual mathematical problems in simplified and visually supported formats. These requirements served as the basis for developing the conceptual design proposed in the next stage.

Ideate Stage: Developing the School ARventure Concept

The ideate stage focused on generating possible design solutions that respond to the learning needs identified in the previous stages. Through a series of brainstorming and design mapping activities, the study developed a conceptual learning environment called School ARventure, which integrates Augmented Reality technology with contextual school environments and simple gamification elements.

Within this framework, several AR based learning features were conceptualized to support different mathematical concepts. The first feature, AR Counting Adventure, is designed to strengthen students' understanding of numbers and quantities by allowing them to interact with virtual objects that can be grouped, counted, and manipulated directly on the screen. Through this interaction, students can observe the relationship between numerical symbols and concrete representations. The second feature, AR Length Virtual Ruler, aims to assist students in learning measurement concepts. Instead of requiring students to manually align a physical ruler, the AR system automatically displays measurement values when the camera is directed toward an object. This approach reduces the influence of fine motor limitations while maintaining students' engagement in the measurement activity. The third feature, Animated Story Quest, addresses the difficulties associated with mathematical word problems. In this feature, textual problems are first presented as short visual narratives that illustrate the situation described in the problem. After viewing the animation, students are guided to identify relevant numerical information and solve the problem step by step.

To strengthen the contextual dimension of learning, the School ARventure framework integrates these AR features with a three dimensional miniature model of the school environment. Locations such as classrooms, libraries, and cafeterias function as markers that trigger AR content when scanned by the application. This design allows mathematical activities to be associated with familiar places within the school environment, thereby helping students connect abstract concepts with everyday experiences.

Figure 2. Conceptual illustration of the School ARventure learning media

Gamification Design Principles

In addition to AR interaction, the School ARventure framework incorporates simple gamification elements intended to support motivation without overwhelming students cognitively. The gamification design was intentionally kept minimal to ensure that the learning experience remains accessible for students with intellectual disabilities. Several design principles were established to guide the development of these elements. Learning missions are designed to consist of short activities that can be completed within a limited duration in order to maintain students' attention. Visual animations are kept simple and avoid rapid transitions that could distract students. Audio feedback is optional and can be adjusted according to students' preferences. Furthermore, the interface layout limits the number of interactive elements displayed on the screen at one time, allowing students to focus on the main learning task. Feedback mechanisms are designed to follow the principle of errorless learning, in which hints and guidance are provided before students experience repeated errors. Progress indicators are presented in a supportive manner without the use of competitive scoring systems.

Discussion

This study set out to develop a conceptual framework for School ARventure, a gamified Augmented Reality learning environment intended to support mathematics learning for students with intellectual disabilities. By applying the early stages of the Design Thinking process, the study explored the learning barriers experienced by students and translated those insights into potential design solutions. The findings provide several important reflections on how mathematics learning environments can be redesigned to better accommodate the needs of learners with intellectual disabilities. The results from the empathize stage revealed that students encountered several challenges when interacting with mathematical concepts in the classroom. In particular, difficulties were observed in connecting numerical symbols with quantities, performing measurement activities that require precise motor coordination, and interpreting mathematical word problems presented in textual form. These patterns reflect broader characteristics commonly associated with learners with intellectual disabilities, including limitations in working memory, slower information processing, and difficulties handling abstract representations (Chmiel et al., 2025). When mathematical tasks require students to simultaneously interpret symbols, read text, and manipulate objects, the cognitive demands may exceed their processing capacity, resulting in confusion or disengagement (Wakhata et al., 2023).

These observations highlight the importance of designing learning experiences that emphasize concrete and visually supported representations (Reyes & Villanueva, 2024). Students in the observed classrooms appeared to respond more effectively when mathematical ideas were introduced through physical objects or visual demonstrations. Nevertheless, traditional manipulatives alone often provide limited interaction and may not fully sustain students' attention during learning activities (Rizk & Hillier, 2022). In this context, Augmented Reality offers a promising alternative because it allows digital objects to be embedded within real environments while maintaining interactive engagement. By enabling students to observe, manipulate, and receive feedback from virtual objects, AR technology can potentially strengthen the relationship between symbolic mathematical concepts and tangible experiences.

Another important aspect emerging from the findings concerns the value of contextual learning environments. The School ARventure concept integrates AR interaction with a miniature representation of the school setting, allowing mathematical activities to be associated with familiar spaces such as classrooms, libraries, or other school areas. Embedding learning tasks within recognizable contexts may help students interpret problems more easily because the situations presented resemble their everyday experiences. Contextual learning has long been recognized as an

effective strategy for supporting conceptual understanding in mathematics education (Manfreda Kolar & Hodnik, 2021). For learners with intellectual disabilities, contextualization may play an even more critical role, as familiar environments reduce the cognitive effort required to interpret abstract or unfamiliar problem situations. The design ideas generated during the ideate stage illustrate how AR technology can be adapted to respond to the specific learning barriers identified in the earlier stages. The AR Counting Adventure feature, for example, focuses on strengthening students' understanding of numbers by allowing them to interact with visual representations of quantities. Similarly, the AR Length Virtual Ruler was conceptualized to address difficulties in measurement tasks by reducing the need for precise manual alignment of physical tools. The Animated Story Quest feature attempts to simplify the interpretation of word problems by presenting contextual information through visual narratives before students engage with the mathematical calculations involved. Together, these features demonstrate how AR based interaction can be designed not merely as a technological novelty but as a targeted response to specific instructional challenges.

In addition to AR interaction, the proposed learning environment incorporates gamification elements intended to support student engagement. However, the design of these elements was deliberately kept simple to ensure that they do not introduce additional cognitive demands. Short missions, limited animation effects, and supportive feedback mechanisms were selected to maintain students' focus on the learning task while still providing a sense of progress and motivation. This approach reflects an understanding that gamification can enhance engagement when implemented in ways that respect learners' cognitive characteristics (Rivera & Garden, 2021).

Beyond the specific design features proposed, the findings also highlight the usefulness of Design Thinking as a framework for developing educational technology in special education contexts (Rusmann & Ejsing-Duun, 2022). By beginning with an in depth exploration of students' learning experiences and teachers' instructional challenges, the design process ensured that the proposed solutions were grounded in real classroom conditions. This user centered approach encourages the development of learning technologies that prioritize accessibility and pedagogical relevance rather than focusing solely on technological innovation (Dritsas & Trigka, 2025).

Taken together, the findings suggest that integrating Augmented Reality, contextual learning environments, and carefully designed gamification elements may offer meaningful opportunities for improving mathematics learning accessibility for students with intellectual disabilities (Lampropoulos et al., 2022). Although the present study focused on the conceptual design stage, the School ARventure framework provides a foundation for future work involving prototype development, usability evaluation, and empirical investigation of learning outcomes in inclusive mathematics classrooms.

Implications

The results of this study suggest several implications for the design of mathematics learning environments intended for students with intellectual disabilities. The conceptual framework of School ARventure demonstrates how Augmented Reality can be utilized to transform mathematical ideas that are typically presented in abstract symbolic forms into experiences that are more visual, interactive, and accessible for learners. Placing learning activities within familiar settings, such as spaces within the school environment, also highlights the potential of contextual learning to make mathematical tasks easier to interpret and more meaningful for students. In addition, the study illustrates how a design process that begins with understanding users' experiences, as emphasized in the Design Thinking approach, can lead to technological solutions that respond directly to real classroom needs. The inclusion of carefully simplified gamification elements further indicates that motivational features can be incorporated into learning environments in ways that support engagement without increasing cognitive demands for students with intellectual disabilities.

Limitations

Although the study provides useful insights for the design of AR-based learning environments, several limitations should be acknowledged. This research focused primarily on developing a conceptual framework and did not proceed to the stages of prototype development or classroom implementation. Consequently, the effectiveness and usability of the proposed School ARventure system have not yet been examined through direct application in learning activities. In addition, the participants involved in the study were drawn from a limited number of special education schools, which means that the learning conditions represented in this research may not fully capture the diversity of instructional contexts found in other schools. Furthermore, while the proposed AR features were designed in response to the learning needs identified during the research process, the technical feasibility and practical constraints associated with developing and operating such a system remain to be explored through further investigation.

Suggestions

Building on the outcomes of this study, several directions for future research can be considered. A natural next step would be the development of a working prototype of the School ARventure learning environment so that the proposed design ideas can be tested in authentic classroom situations. Such implementation would allow researchers to examine how students interact with the AR features and whether the system effectively supports their understanding of mathematical concepts. Future studies could also investigate the impact of AR-supported learning on students' engagement, conceptual comprehension, and problem-solving performance through empirical classroom experiments. In addition, further research may explore how teachers integrate AR-based tools into their instructional practices and how such technologies can be aligned with broader inclusive learning frameworks, including approaches such as Universal Design for Learning that emphasize flexibility and accessibility in educational environments.

CONCLUSION

This study proposed the School ARventure framework, a conceptual design for a gamified Augmented Reality learning environment intended to support mathematics learning for students with intellectual disabilities. Through the early stages of the Design Thinking process, the research examined the learning challenges encountered by students and used these insights as a basis for developing potential design solutions. The findings indicate that students often struggle with linking numerical symbols to quantities, completing measurement activities that require precise motor coordination, and interpreting word problems presented in written form. In response to these challenges, the School ARventure concept introduces several AR-based learning features designed to present mathematical ideas through interactive visual representations, contextual learning situations, and carefully simplified gamification elements. By situating learning activities within familiar school environments and reducing unnecessary cognitive demands, the framework aims to make mathematical concepts more accessible and meaningful for students with intellectual disabilities. Although the study is limited to the conceptual design stage, the proposed framework offers a foundation for further work involving prototype development, classroom implementation, and empirical evaluation of AR-supported mathematics learning in inclusive educational contexts.

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